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Origin of defects on targets used to make EUV mask blanks

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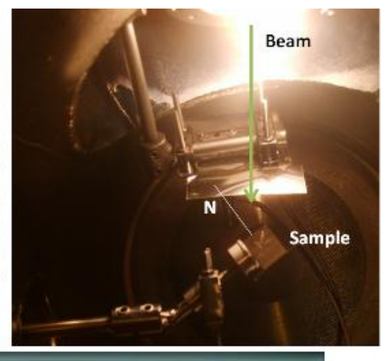
Abstract

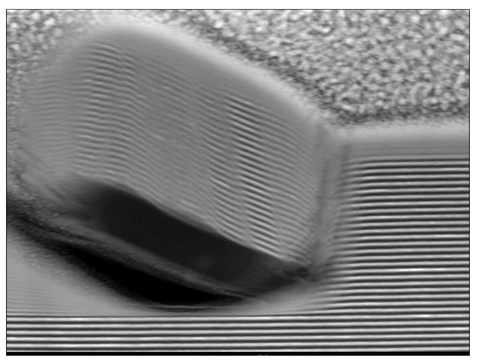
In EUV lithography mask production, one source of contaminants originates from the targets used to sputter material onto the substrates. In particular, silicon appears to produce more contamination on rough regions of the silicon target. The features were found to be triangular hillocks pointing in the direction of the incident beam. The aim of this research is to prevent this particle formation on the target and thus eventually on the substrate. Both Si and Ru targets were sputtered using different ion beam conditions to understand particle formation mechanisms on the target and explore the ion beam conditions that can mitigate particles. Additionally, a 3D Monte Carlo computer model has been written to help understand the growth of the hillocks. It is clear from these experiments that the way to remove the particles from a surface is to have the surface exposed to an incident beam of 0º plus or minus a few degree.

Broad-Area Ion-Gun Tool (BAIT) at CPMI



- The Broad-Area Ion-Gun Tool (BAIT) was originally built for line-edge roughness experiments.
- It consists of a vacuum chamber that is evacuated by a 200 L/s turbo pump. An ion beam with a 10cm diameter beam is installed at the top of the vacuum chamber.
- Any gas can be used, for these experiments Ar is used.
- The surface angle can be changed with respect to the beam direction.
- A beam neutralizer is also present.

Experimental results



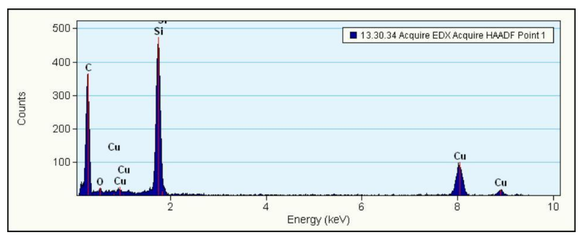
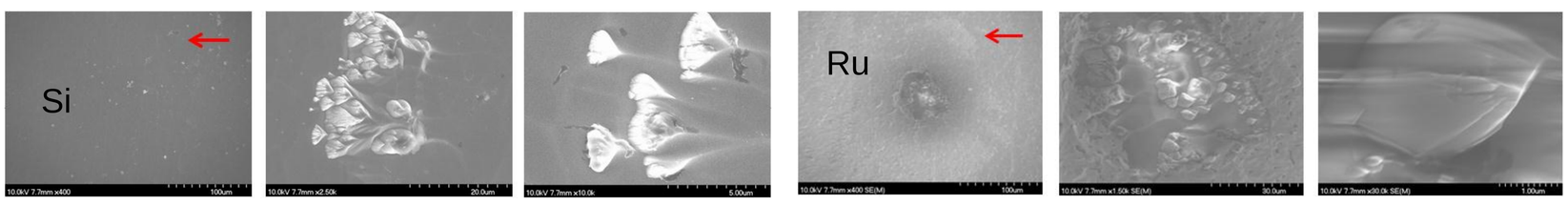


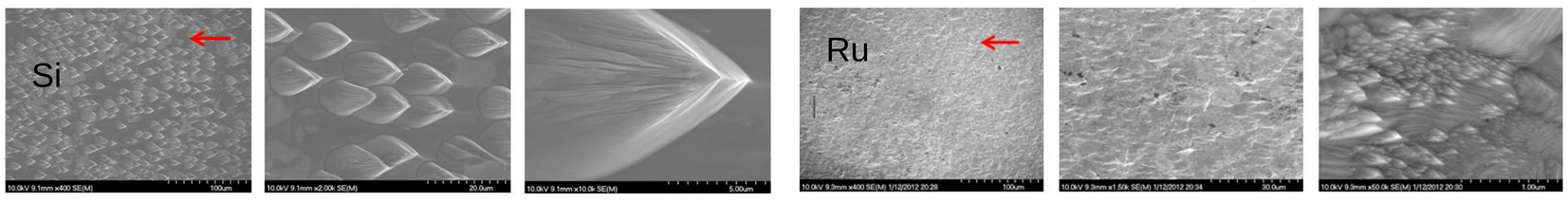
Fig. 1 TEM (a) and EDX (b) analysis of a multilayer with Si defects (provided by SEMATECH)

Origin of defects



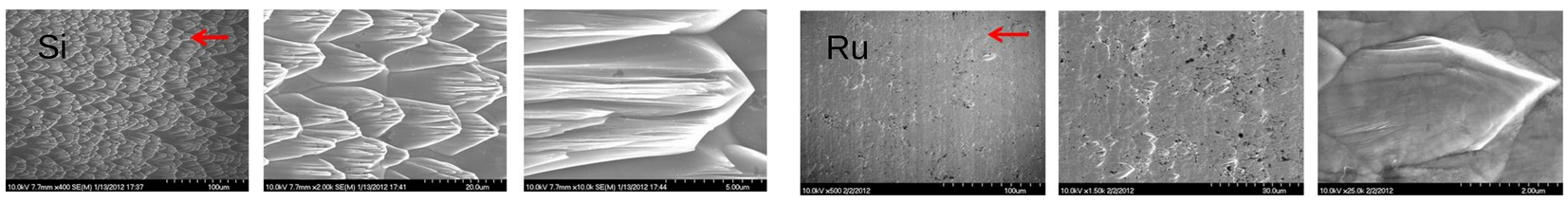
(a) Beam conditions were E=600eV, θ=35º exposed for t=6 hours.

(d) Beam conditions were E=600eV, θ=35° and exposure time t=6 hours.



(b) Beam conditions were E=600eV, θ=54º exposed for t=6 hours.

(e) Beam conditions were E=600eV, θ=54° and exposure time t=6 hours.



(c) Beam conditions were E=600eV, θ=75º exposed for t=6 hours.

(f) Beam conditions were E=600eV, θ=75° and exposure time t=6 hours.

Fig. 2 SEM images of samples (100µm, 20µm, 5µm resolution) taken from sintered Si target and Ru target produced by the BAIT. The arrow indicates the direction of the beam.

Removal of defects

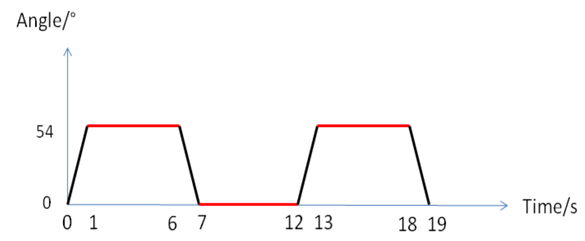


Fig. 3: The time series used to remove the hillock features.

A sample was run for 6 hours in BAIT and would swap between 0° and 54° every 5-6 seconds, see figure 7. It showed that the surface was cleaned of the majority of surface roughness, figure 8 shows this.

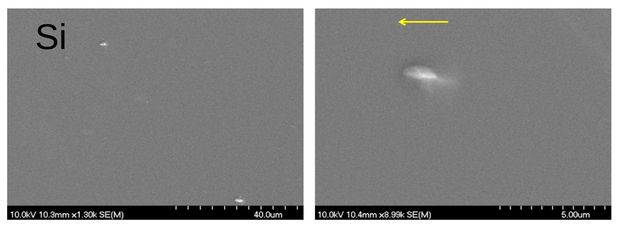
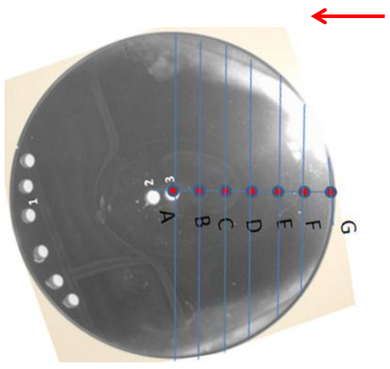
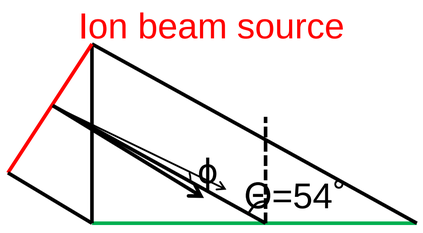


Fig. 4: SEM of a sample that has been run alternating between 0° and 54° for 6 hours.

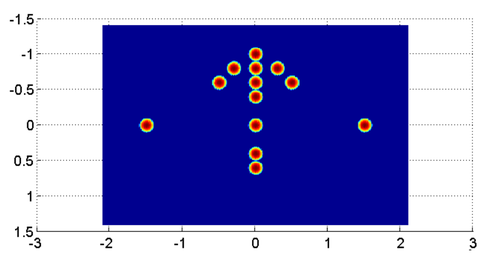
3D Monte Carlo Modeling



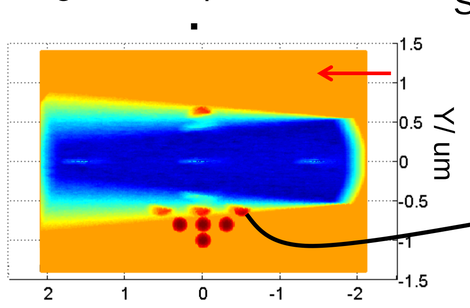
Si Target after sputtered

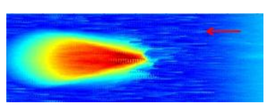


Incident angle Θ =54°
Spreading angle Φ=10°



Original target surface





Zoom in

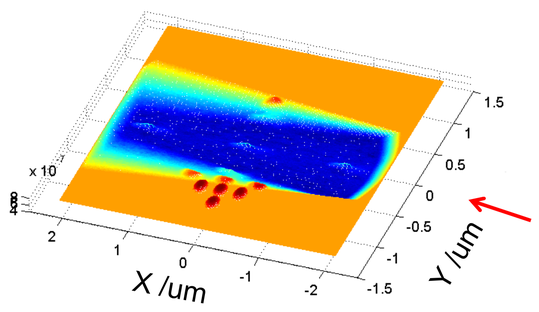


Fig. 5 Monte Carlo simulation of angular spread

Summary

Mesa formation seen on the surface of both Si targets and Ru targets was analyzed experimentally as well as theoretically and simulated using a Monte Carlo program. Experiments on both Si and Ru targets sputtered by angles of 35°, 54°, 75° with Ar at 600 eV have been done. A 3D Monte Carlo computer model (iSAM) was written to understand the shape of mesas with different incident angles of ion beam (0º, 35 º, 54 º, 75º) that agrees with the shapes of mesas seen in the experiments. It is clear from these calculations and experimental results that the way to remove the particles from a surface is to have the surface exposed to a normal incident beam.

Acknowledgements

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